哈爾濱工業大學（深圳）
HARBIN INSTITUTE OF TECHNOLOGY

实验报告

开课学期：2024 春季

课程名称：机器人学导论

实验名称：

实验性质：

实验时间：3.21 地点：K320 实验台号

学生专业：自动化

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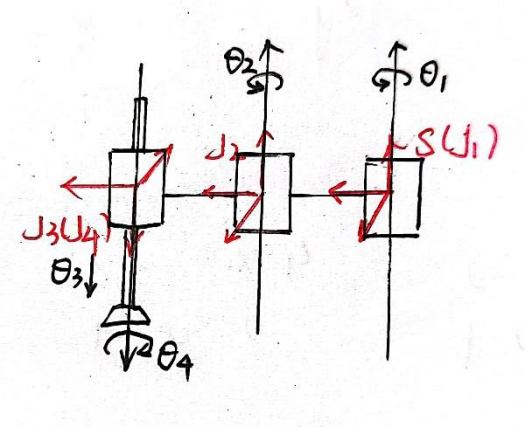
评阅教师：

报告成绩：

实验与创新实践教育中心印制

实验使用 SCARA 机器人。

1.机器人初始姿态如图。其中世界坐标系为 S，关节坐标系为 J_1~J_4，初始姿态下 S 与 J_1 重合，J_3 与 J_4 重合。



2. 对四轴有 $\xi_1 = [0\ 0\ 0\ 0\ 0\ 1]^T, \xi_2 = [0\ l_1\ 0\ 0\ 0\ 1]^T, \xi_1 = [0\ 0 -1\ 0\ 0\ 0]^T, \xi_4 = [0\ -(l_1+l_2)\ 0\ 0\ 0\ 1]^T$。由 $\mathrm{g_{st}}(0) = \begin{bmatrix} I & [(l_1+l_2)\ 0\ 0]^T \\ 0 & 1 \end{bmatrix}$，可得

$$\mathrm{g_{st}}(\theta) = e^{\widehat{\xi_1}\theta_1} e^{\widehat{\xi_2}\theta_1} e^{\widehat{\xi_1}\theta_1} e^{\widehat{\xi_1}\theta_1} \mathrm{g_{st}}(0)$$

使用 Matlab 求解正运动学:

```
syms t1 t2 t3 t4 l1 l2
g1 = [ cos(t1)  -sin(t1)  0  0; ...
       sin(t1)   cos(t1)  0  0; ...
            0         0   1  0; ...
            0         0   0  1];

g2 = [ cos(t2)  -sin(t2)  0   l1*(1-cos(t2)); ...
       sin(t2)   cos(t2)  0     -l1*sin(t2); ...
            0         0   1              0; ...
            0         0   0              1];

g3 = [ 1  0  0   0; ...
       0  1  0   0; ...
       0  0  1  -t3; ...
       0  0  0   1];


g4 = [ cos(t4)   sin(t4)  0  (l1+l2)*(1-cos(t4)); ...
      -sin(t4)   cos(t4)  0     (l1+l2)*sin(t4); ...
            0         0   1                 0; ...
            0         0   0                 1];

gst0 = [1  0  0  l1+l2; ...
        0  1  0     0; ...
```

```
        0   0   1      0; ...
        0   0   0      1];
gst = simplify(g1 * g2 * g3 * g4 * gst0)
```

解得末端位置：

$$p_x = l_1 \cos(\theta_1) + l_2 \cos(\theta_1 + \theta_2),$$

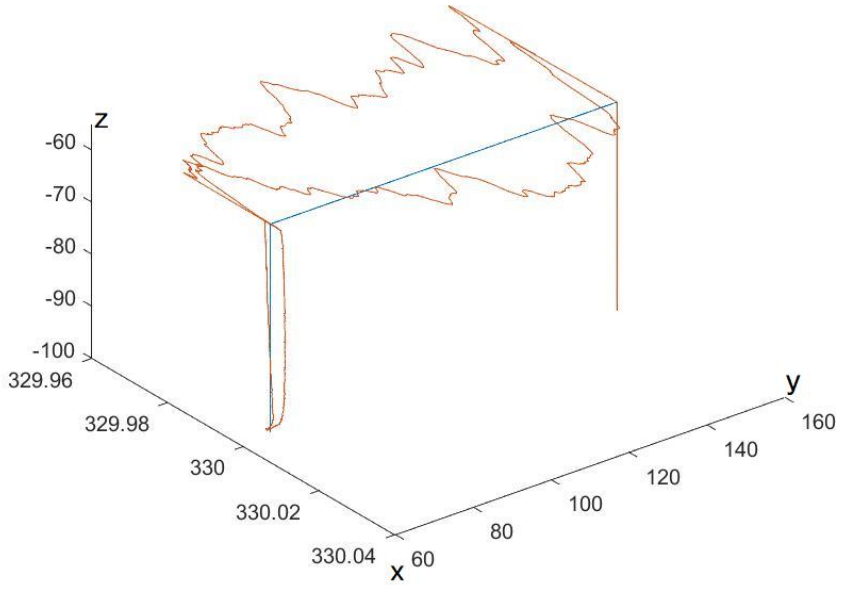
$$p_y = l_1 \sin(\theta_1) + l_2 \sin(\theta_1 + \theta_2),$$

$$p_z = -\theta_3$$

利用 Matlab 绘制轨迹：

```
joint_data = csvread("logged_data.csv");
deg2rad = 0.017453292519943295769236907684889;
l1 = 250;
l2 = 250;

t1 = joint_data(1:length(joint_data),1) * deg2rad;
t2 = joint_data(1:length(joint_data),2) * deg2rad;
t3 = joint_data(1:length(joint_data),3);
t4 = joint_data(1:length(joint_data),4) * deg2rad;

gstx_ref = l2*cos(t1 + t2) + l1*cos(t1);
gsty_ref = l2*sin(t1 + t2) + l1*sin(t1);
gstz_ref = -t3;

t1 = joint_data(1:length(joint_data),5) * deg2rad;
t2 = joint_data(1:length(joint_data),6) * deg2rad;
t3 = joint_data(1:length(joint_data),7);
t4 = joint_data(1:length(joint_data),8) * deg2rad;
gstx_fdb = l2*cos(t1 + t2) + l1*cos(t1);
gsty_fdb = l2*sin(t1 + t2) + l1*sin(t1);
gstz_fdb = -t3;

hold off
plot3(gstx_ref, gsty_ref, gstz_ref)
hold on
plot3(gstx_fdb, gsty_fdb, gstz_fdb)
```

机器人在笛卡尔空间运动轨迹如图，其中蓝色为规划轨迹，橙色为实际执行轨迹。



3.机器人码垛指令如下:

```
System.Speed 10
'Location P1
'Location P2
'Location P3
'Location P4

P1 = 330.006,149.999,-55.001,0.000,180.000,-57.201
P2 = 330.006,149.999,-95.001,0.000,180.000,-57.201
P3 = 330.006,60.999,-55.001,0.000,180.000,-57.201
P4 = 330.006,60.999,-95.001,0.000,180.000,-57.201

IO.Set DOUT(20103),0
Move.WaitForEOM
Move.Line P1
Move.Line P2
IO.Set DOUT(20103),1
Move.Line P1
Move.Line P3
Move.Line P4
Move.WaitForEOM
IO.Set DOUT(20103),0
Move.Line P3
Move.Line P1
```